CORNELL EXTENSION BULLETIN 440

New York State College of Agriculture

the Storage of Apples

BY R. M. SMOCK

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THE STORAGE OF APPLES

R. M. Smock

Apples are held in various types of storages to provide a regulated supply to the market throughout the winter and spring. Whether or not the apple grower will get enough higher price for his fruit to realize a profit after paying storage costs depends upon several factors. One of the most important of these is the quantity of apples stored by other growers. On the other hand, large numbers of apples must be stored or there would be market gluts in the fall at harvest time. Good marketing demands a regulated supply of good fruit throughout the whole selling period. Only occasionally does it pay a grower to store apples lower in grade than U.S. 1. Of course, if the grower stores his fruit field run (without any grading) his off-grade fruit must be stored.

TYPES OF STORAGES

This bulletin does not attempt to describe in detail the various types of storages.

Common storage

Common storage is sometimes called the *air-cooled* or *ventilated* type of storage. An insulated building is cooled during the fall months by introducing air during cool nights and keeping the storage closed during warm days. The outside air is introduced into and blown out of the building through suitable ports. The opening and closing of these ports and exhaust fan operation can be controlled with thermostats which operate depending upon inside and outside temperatures. The main limitation of common storages is that outside fall temperatures are not usually cold enough to properly cool the storage. Details of construction and operation are given in Cornell Extension Bulletin 453, *The Air Cooled, or Common, Storage and Its Management.*

Refrigerated storage

With refrigerated storage, an insulated building is cooled by mechanical refrigeration. Many refrigerated cold storages are in operation on New York farms. For the most part, this bulletin will discuss the behavior of apples in refrigerated cold storage. A full description of building and operation of such storages may be seen in Cornell Extension Bulletin 724, *Farm Refrigerated Storage.*

Controlled atmosphere storage

Controlled-atmosphere (CA) storage involves the use of low temperatures in an insulated, gastight room. The atmosphere in the storage is modified so that it has a higher carbon dioxide and lower oxygen content than normal. This type of storage is used primarily as a supplement to refrigerated storage for holding apples late into the winter and spring. A description of the construction and operation of such storages is given in Cornell Extension Bulletin 759, *Controlled-Atmosphere Storage of Apples.*

Freezing storage

This type of storage is really a fruit processing technique. It involves storage of quickly frozen apple slices for pie and other baking purposes. After peeling and slicing, the apples are "blanched" with steam or sodium bisulfite to prevent browning of the flesh. Sugar is added to the slices and the product is quickly frozen at minus 20° to 40° in sealed metal cans and stored at 0°F. This bulletin does not concern itself with freezing storage.

CONSIDERATIONS BEFORE STORAGE

Determining maturity of fruit at harvest

APPLES that are to be held for long periods must be of the proper degree of maturity when picked. Immature apples are likely to shrivel in storage and to be especially susceptible to storage diseases such as scald and bitter pit. Eating quality is low in immature apples and they do not have as attractive a color as properly matured fruit. On the other hand, apples too mature when picked are likely to have a short storage life and break down prematurely. Judging when to pick is more of an art than a science at present. Almost every index of maturity has to be defined for not only a given variety but for a given location, season, soil type, and level of tree nutrition. Some of the more useful measures of maturity are discussed in Cornell Extension Bulletin 750, *Harvesting, Handling and Packing of Apples.*

Care in handling

The extreme importance of carefully handling even the harder fleshed varieties during harvesting, sizing, grading, packing, stowing, and hauling cannot be overstressed. It is estimated that many lots of apples are handled as many as 30 times from the time they are picked until they reach the consumer. Each handling operation is a possible point of bruising. Bruised fruit is unsightly and brings a lower selling price. It is

one of the main defects appearing on New York apples offered for sale. Even slight cuts in the skin serve as excellent points of entry for spores of decay organisms. The main cause of rotten fruits in storage is rough handling. Badly bruised fruits actually ripen faster in storage.

Stowing the fruit

It is a "snare and a delusion" to look at a thermometer in the aisle of a cold-storage room and assume that all of the stored fruit in the room is at that temperature! The real issue revolves around the core temperatures of the fruit at the center of the stack. Some storage operators seem to be happier not knowing that it is taking 3 or 4 weeks instead of the desired 3 to 4 days to bring core temperatures of fruit down to 32°F. after the fruit is brought into the room. Rapid removal of field heat is important and cannot be accomplished unless there is good air distribution. As a general rule, there should be moving air passing by at least two sides of every container of fruit.

An elaborate system for air distribution is useless if poor stacking undoes all that the duct system is supposed to do. The writer has seen many examples of apples stacked in front of duct outlets or in front of diffuser outlets.

It is difficult to tell exactly how to stack the fruit because containers vary widely. For example, apples may be stored in the western type of box that has no openings for air passage, or they may be packed in the northeastern type of box which has cleats on the ends that allow some air passage through even tightly packed boxes in a stack. They may be packed in baskets which allow ample circulation through the stack. They may be stacked in open field crates which allow some air movement across the tops of the fruit.

Rules for stacking western boxes of fruit (apples and pears) have been fairly well standardized. Lines are painted on the floor of the storage rooms to indicate the spaces for the rows of boxes. A uniform spacing of from 2 to 3 inches between rows is as practical as wider spacing if there is enough head room between the boxes and the ceiling. The rows should be so laid out that the general direction of air movement is along the rows instead of across them.

A 4-to-6-inch spacing at the side walls is desirable. Stacking against outside walls should be avoided because there is always heat leakage through the walls into the room during the warmer months. A side rail on the walls prevents stacking against the walls.

With unpacked apples in northeastern boxes or field crates, it is probably not so important to leave this full 3-inch spacing, but it is

important to make sure that air can get past at least two sides of each container. Lidded boxes packed on their sides must be spaced so that air can move past each side of the box (figure 1).

An experimental study was made at Cornell on the effect of the method of stacking packed boxes of apples laid on their sides. One method was to stack the rows of boxes tightly together. By doing so, air spaces were left because of the cleats on the ends of the boxes, but these air spaces did little good, because air flow was from the side wall to the aisle and these air spaces between the boxes were at right angles to the air flow. Hence, very little air passed through this stack.

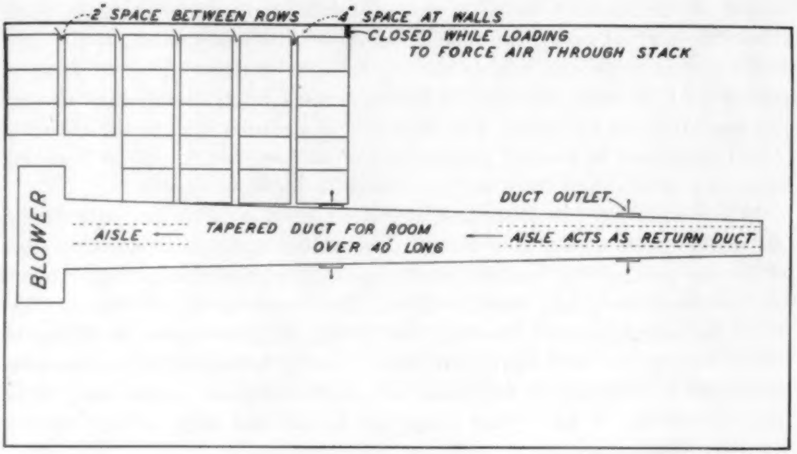
The second method was to stack these packed boxes with a 3-inch space between the rows of crates. Temperature records were kept, by thermocouples, of the core temperatures of the center apples in the boxes in various points in the two stacks. It took three days longer to remove the field heat in the tightly stacked apples than in the others. Possibly even more important was that core temperatures in the center of the tightly piled stack of apples stayed from 2 to 3 degrees higher than in the center of the stack with 3-inch spacing. This temperature difference persisted during the 6 weeks that observations were made. It was presumably due to heat of respiration that was not properly removed in the tightly packed stack. This difference was not observed on the edges of the stack. Pressure tests on apples taken from the center of these two experimental stacks showed that the apples were softer in the tightly packed stack after 2½ months of storage than in those stacked 3 inches apart.

If storage type cartons are used, the cartons must have ample ventilation slits. Unventilated cartons cool very slowly and stay warmer than the surrounding air during storage. Such cartons must be spaced so that there is moving air past the long sides of each container.

These general principles of stowage apply to pallet operations also. While the pallets themselves usually allow ample air movement around each unit load of 36 or more boxes, some provision must be made for air movement past the individual containers.

The exact method of stacking may depend in part not only on the type of container used but also on the method of air distribution used. If a gravity air-flow system is used with cooling coils, spacing of containers is even more important than with forced-air circulation. With some types of forced-air circulation, excessive spacing between the rows may do more harm than good, because air is allowed to by-pass the containers.

One system of stacking and air distribution that is in use and that has been tested experimentally is described briefly. The air is taken down the



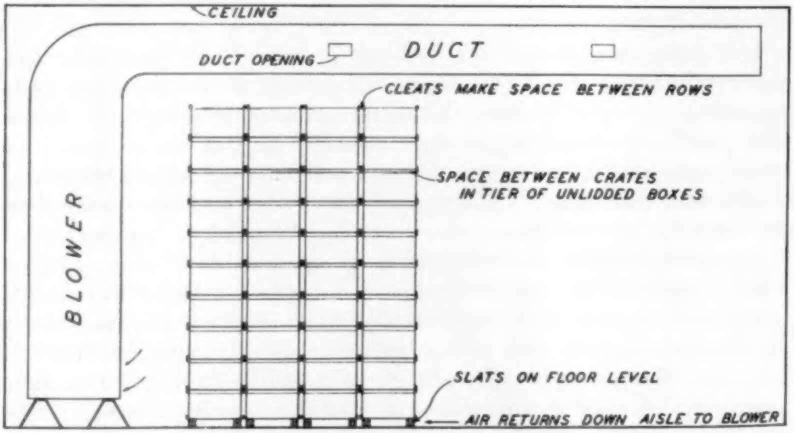


FIGURE 1. STACKING PLANS FOR NORTHEASTERN APPLE BOXES IN FORCED AIR CIRCULATION STORAGE

Upper diagram is looking down on a room with stacks of lidded boxes stacked on their sides. Lower diagram is with stacks of unlidded boxes stacked right side up. Diagrammed from aisle and facing stack of boxes (not drawn to scale)

length of the room in a central duct. Outlets along the sides of the duct direct the air out across the top of the stack. A 4-inch spacing at the side walls acts as a plenum and builds up a slight pressure. The air is then forced back through the stack. The boxes must be so spaced that air can get past them on two sides. The aisle acts as a return duct to the blowers. The boxes must be stacked parallel to the aisle so that the spaces between boxes act as channels from the wall space to the aisle (figure 1).

In the situation just described, the aisle serves a useful purpose in the air distribution set-up as a return duct. Aisles may, however, upset an otherwise good set-up for air distribution. Those that run parallel to the air flow from ducts may channel the air. Since such aisles are often needed from the standpoint of handling the fruit, curtains should be hung in them during the time that field heat is being removed. Alleys running perpendicular to the air flow from the air distribution system may allow short circuiting of air. These alleys can be bridged over the top during the "pull-down" period.

Since almost every room presents a separate problem, a little study is often necessary to decide how best to distribute the air, keeping in mind the general principles discussed here.

It is sometimes assumed that because a blower has a high cubic feet per minute rating that air must go to all parts of the room. Actual study has shown that without ducts the air tended to become turbulent at the mid portion of the room and short circuited back to the blowers. The front corners of the room (the blowers were at the front of the room) were completely "dead." Usually ducts are needed in a room more than 40 feet long. In wide rooms two ducts may be needed. The duct must be carefully designed so that there is an equal static pressure *along its whole length*. Outlets must be designed so that each delivers the required amount of air. The writer has observed ducts in which air was actually being drawn into the duct outlets from the room. The first slot openings are often the poorest because of high air velocities in the duct at those points. Unless air is coming out of the first slots, the front corners of the room will be "dead." Sometimes a scoop at the first slot opening is necessary to direct air to the front corners of the room. Such a scoop extends into the duct about two inches and is curved to deflect the air to the front corners of the room.

LIFE PROCESSES OF THE APPLE IN STORAGE

Respiration

IT MUST be remembered that the apple is a living organism even though it is separated from the parent tree. If the apple is not first destroyed

by decay or some other disease, it dies of old age. The apple carries on respiration, a process characteristic of living things. In respiration the natural fruit sugar is consumed or oxidized in the presence of oxygen in the air, and carbon dioxide, water vapor, and heat are given off as products.

Factors affecting rate of respiration

The rate of living, or more specifically, the respiration rate, of apples is governed by the temperature. For every 18°F rise in temperature the respiration is doubled or trebled. For example, an apple held at 50°F ripens and respires about three times as fast as one held at 32°F and one held at 68°F about three times as fast as one held at 50°F. For example, in respiration studies of Cortland, it was found that one day at 70°F was equivalent to one week at 32°F. This effect of temperature is the underlying principle of cold storage.

The age of the fruit has a profound effect on its respiration rate. Figure 2 shows that McIntosh apples do not have a uniform rate of respiration at a constant temperature of 74°F. Apples do not approach the eating ripe condition until after they are past the respiratory peak seen in figure 2. Some varieties such as Rhode Island Greening would normally be picked before the respiratory rise begins. Others like Golden Delicious would not be picked until the peak has passed on the tree because of the importance of getting full maturity with this variety on the tree. If apples go into storage after they are well past the respiratory peak, they cannot be expected to come out of the storage in a "young" condition.

The amount of oxygen in the atmosphere influences the respiration rate. Normal air is 21 per cent oxygen. If the oxygen is reduced to three per cent, the respiration rate is greatly lessened. This principle is used in controlled atmosphere storage. If the oxygen level becomes too low, the apples ferment and produce alcohol.

If carbon dioxide is allowed to accumulate around the fruit, the respiration rate is lessened. This principle is also used in controlled atmosphere storage. The amount of carbon dioxide must be carefully regulated since high concentrations may be toxic to some varieties.

The presence of ripening gases such as ethylene may stimulate the respiration of apples particularly at high storage temperatures. Apples that have passed the respiratory peak cannot have their respiratory rate increased. In general, only those apples that are low on the respiratory rise (see figure 2) can have their rate influenced by ripe apple vapors.

Rough handling which results in bruising stimulates the respiration of apples, particularly when they are held at high temperatures (figure

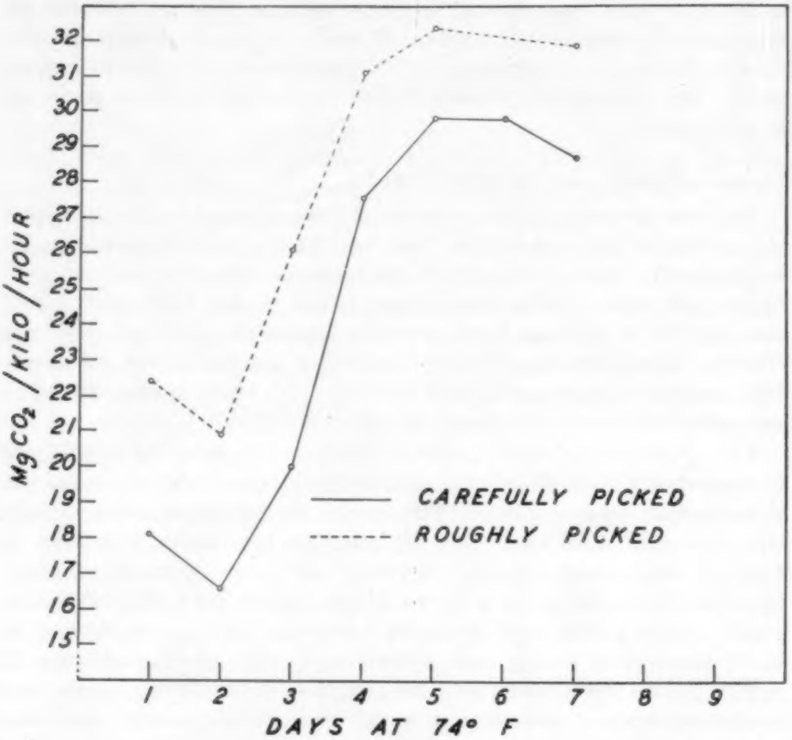


FIGURE 2. EFFECT OF CAREFUL AND ROUGH PICKING METHODS ON RESPIRATION (LIVING RATE) OF MCINTOSH APPLES

"Carefully picked" apples were harvested into pails and hand-placed from pails into field crates. "Roughly picked" were picked carelessly into drop-bottom picking bag and dropped carelessly from picking bag into field crates.

2). Other factors affecting respiration such as stop-drop sprays, season, nutritional level, and freezing injury will be discussed later. Relative humidity does not directly affect the respiration rate.

Heat of respiration

The heat evolved by the fruit in respiration must not be overlooked in computing the engineering requirements of an apple storage. Of course, the amount of heat evolved is dependent upon the temperature of the fruit. When the fruit is first put into the storage, the amount of heat being given off may be considerable; but even at 32°F. the heat of respiration is a measurable quantity and one to be reckoned with. If heat

loss from the container and the air space in the container are disregarded, a bushel of apples will raise its fruit temperature from 32° to 33° F. in four days. If one makes the same assumption, at 66°F. a bushel of apples will raise its fruit temperature to 68°F. in twenty-four hours.

At 32°F. a ton of "apples" will give off about 660 British thermal units a day. At 40°F. it will give off from 1100 to 1760 British thermal units, at 60°F. from 4400 to 6600, and at 85°F. from 66,000 to 68,400.

It can be seen, then, that in cooling apples to a desired temperature one must take into consideration not only the latent, or field, heat of the fruit but also the heat of respiration. In calculating the heat of respiration, it is usually assumed that respiration continues at the same rate throughout the season if the temperature remains the same. Calculations of refrigeration requirements are given in Cornell University Agricultural Experiment Station Bulletin 724, *Farm Refrigerated Storages.*

Transpiration

Transpiration involves the loss of water in vapor form from living tissues. Loss of water results in loss of weight, shrivelling, and reduced eating quality. Transpiration must always be kept at a minimum in storage for this reason.

Water vapor moves out of the intercellular spaces of the fruit into the storage atmosphere when the concentration of water vapor in the surrounding air is less than that inside the fruit. The water vapor concentration of the intercelluar spaces of an apple is normally saturated. That is, the relative humidity of the spaces is 100 per cent. When apples are held in an atmosphere with 80 per cent relative humidity, it is obvious that water vapor will leave the fruit. This is true because gases always move from a point of high to a point of low concentration. A second consideration that affects moisture loss from the fruit is the temperature of the fruit and the temperature of the air. When the temperature of the fruit is higher than that of the air, water will leave the fruit. This temperature difference is inescapable when fruit is placed in storage. The only practical answer to minimizing this problem is to practice rapid cooling so that this temperature difference exists for a short time.

The higher the temperature in storage the higher should be the relative humidity. Weight losses in Golden Delicious at different temperatures and relative humidities may be seen in figure 3.

Another factor which affects water loss is air movement in the storage. This effect is often overemphasized. If the relative humidity in storage is 90–95 per cent, the effect of even high air velocities is not large. If the

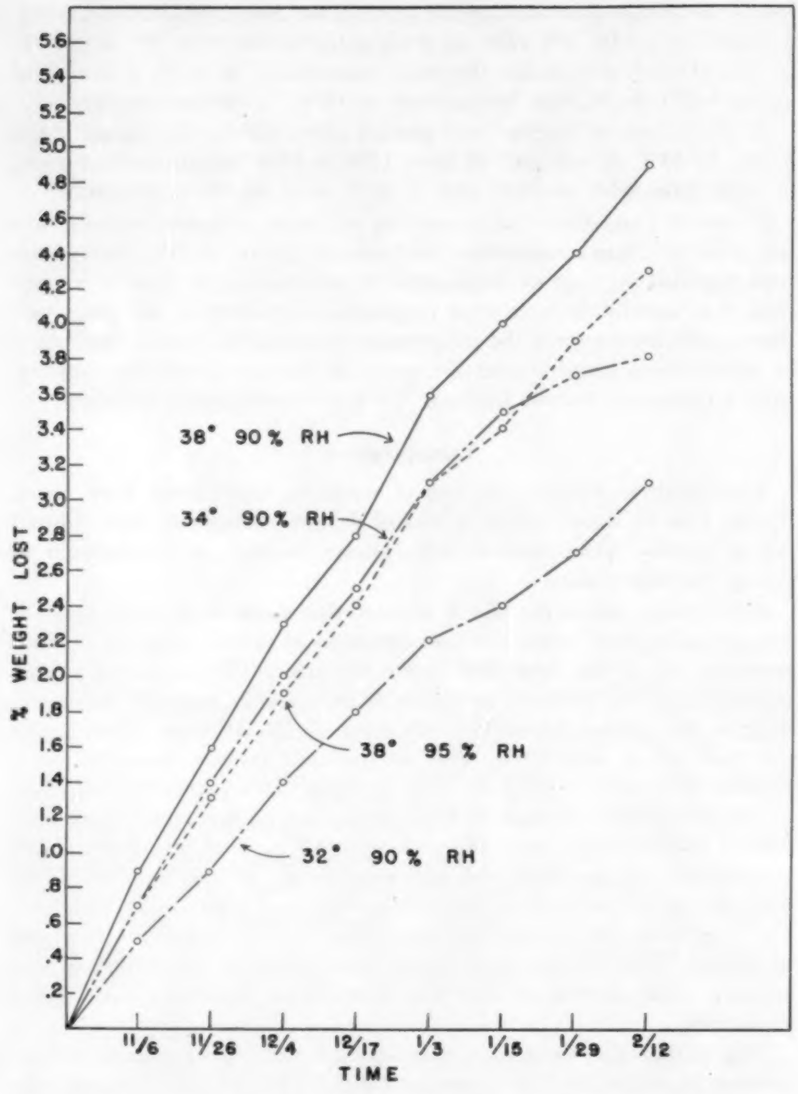


FIGURE 3. WEIGHT LOSSES IN GOLDEN DELICIOUS AT DIFFERENT TEMPERATURES AND RELATIVE HUMIDITIES (RH)

relative humidity is 80–85 per cent, the effect of high air movement can be very serious in drying out the fruit.

Characteristics of the fruit itself may determine how much it will transpire and lose weight. A bushel of small fruits will lose more weight than a bushel of large fruits. This is true because transpiration is from the surface of the fruit, and there is more total surface area in a bushel of small fruit than in a bushel of large fruit. Fruit with russetted skin resulting from frost damage or spray injury will transpire faster than normal fruit. A variety such as Golden Delicious transpires rapidly because of cracks and breaks in the cuticle, which is the very outside layer of the skin.

FACTORS AFFECTING THE STORAGE LIFE OF APPLES

TWO IMPORTANT factors that affect the length of keeping of apples in storage have already been discussed, namely the maturity of the fruit and the care with which it is handled.

Immediate Storage

Apples should be placed in storage as soon as possible after picking. Studies with McIntosh and Cortland show that delay after picking at 70°F for one day takes at least a week off the potential storage life at 32°F. Delay in storage can increase storage troubles such as bitter pit, decay, and shrivelling.

When the nights are cool (i.e. 30–45°F) apples picked in the late afternoon can be left in the orchard to lose some of their field heat. Such apples should be left in crates only one layer deep. If large stacks of crates are left in the orchard they do not lose their field heat rapidly. They should be left where the late afternoon sun will not strike them.

Temperature

As has been already pointed out, temperature affects the ripening rate of fruit in storage, the moisture loss from fruit, and the growth of molds and decay organisms.

In general, the lower the temperature in storage the slower the fruit will ripen, but several considerations must be kept in mind when determining the best storage temperature.

At what temperature does the fruit freeze? The exact freezing point varies slightly from variety to variety but usually is between 27 and 28°F. Hence, apples must be stored at temperatures of 29° or above. Some varieties such as Delicious and Golden Delicious can be stored satisfac-

torily for long periods at 30°F. If a temperature of 30°F. is selected for a storage room, it must be certain that air distribution of the cold air is such that none of the fruit drops below 29°F at any time. Otherwise, the fruit will freeze.

How long are the apples to be kept? If all varieties are to be removed by January or February at the latest, some saving in refrigeration can be had by storing at 34–36°F. If they are to be kept until late winter or spring, the storage temperature must be lower.

Is the variety stored very susceptible to low temperature troubles such as brown core, soggy breakdown or soft scald? For example, in many seasons Jonathan stored at 32°F. will develop a great deal of soft scald. Brown core may be severe in McIntosh in certain seasons when stored at 32°F. until February or March.

Is the variety subject to troubles such as scald and bitter pit? These troubles usually develop more slowly at 30–32°F. than they do at higher temperatures.

Is apple maggot serious? If so, a temperature of 32°F. is needed for a month to inactivate the larvae in the fruit. This is especially pertinent for fruit that is to be exported.

The practical question remains as to what temperature to use for mixed varieties in New York. Certainly the most commonly used temperature is 32°F. and that is the usual recommendation for mixed variety storage. Certainly a variety like Delicious can be kept somewhat longer at 30°F. than at 32°F., yet in a mixed variety storage room, Jonathan, Rhode Island Greening, and Baldwin and McIntosh might have more low temperature disorders.

Rapid cooling

Once the fruit is placed in storage, the fruit should be cooled just as fast as is economically feasible. Core temperatures of fruit in the centers of the stacks should be down to 32–33°F in 3 to 4 days after being brought into the room. By flooding the fruit with ice water (hydrocooling), it is possible to remove about half of the field heat in 15–20 minutes and practically all of it in an hour. It is doubtful if hydrocooling before storage can be economically justified with apples. Field heat can be removed rapidly enough with adequate sized refrigeration machinery, proper air distribution, and not loading the room faster than the machinery can cool it in 3–4 days.

Figure 4 shows the effect of different rates of cooling on the firmness of McIntosh after storage. Some rooms do not remove the field heat in less than two weeks or longer.

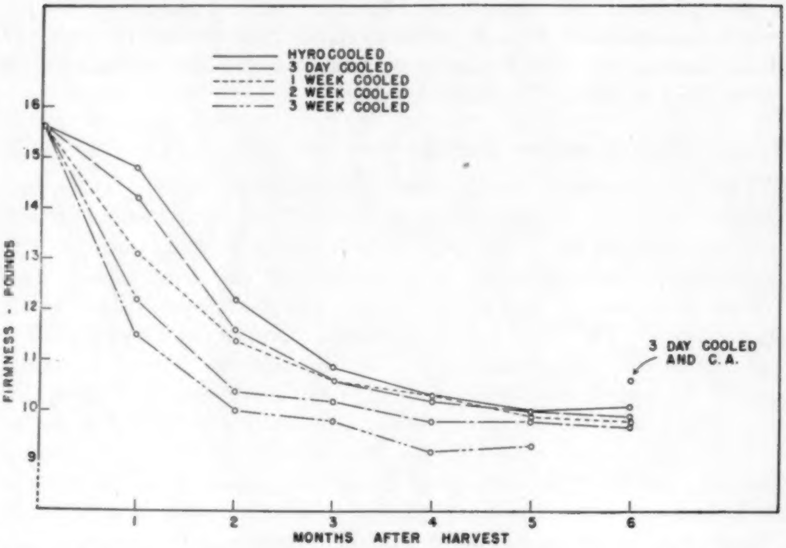


FIGURE 4. INFLUENCE OF RATE OF COOLING ON SOFTENING OF MCINTOSH APPLES IN 32° F. AIR STORAGE AND CONTROLLED ATMOSPHERE (CA) STORAGE

Photo by G. D. Blanpied

Relative humidity

Relative humidity may be defined as the percentage of saturation of the air with water vapor at any given temperature. Air at any temperature has a given capacity to hold water vapor. As the temperature increases, its capacity to hold water vapor increases. For example, if air was fully saturated with water vapor at 32°F, there would be a fog in the room. If the temperature was raised one degree the fog would disappear.

To entirely prevent any weight loss from fruit, the relative humidity should be 100 per cent—the same as it is inside the fruit. There are practical objections to using 100 per cent relative humidity, however. The cooling surfaces inevitably keep removing water vapor from the air because there must be a temperature gradient between the coils and the room air. If the relative humidity were maintained at 100 per cent, there would be excessive mold growth on the fruit, the crates, and on the walls. Molds grow in a free water surface and there would be such water surfaces with a saturated atmosphere in the room.

As a practical and compromise figure, a relative humidity of 90 per cent is recommended. Even 95 per cent relative humidity can be employed if air distribution is good enough to prevent any local condensation of water. This is difficult to attain, however.

Factors affecting relative humidity

The most important factor influencing relative humidity is the temperature difference between air going into and coming out of the blower. This temperature difference must be kept just as small as possible. The temperature difference (TD) is determined by coil temperature, total volume of air moved through the blower, and the "by-pass factor" of air in the blower. The latter is a consideration because not all of the air is brought to coil temperature as it passes through the blower. Certainly one of the biggest considerations here is *coil temperature*. If air which is saturated with water vapor (100 per cent relative humidity) at 30° as it leaves the cooling coils goes out into a room at 32°F., the relative humidity will be 90 per cent, other things being equal. If saturated air at 25°F. goes out into a room at 32°F. the relative humidity will be about 75 per cent. To attain this small TD, there must be a large surface area of coil surface. It would be possible to have a TD of only 1/4 degree, but the coil area would be so big that it would not be economically feasible. In some instances, particularly in rooms held at 36 or 38°F., refrigerant temperature may be so low it may be necessary to install a back pressure control valve to operate at higher back pressures and hence higher coil temperatures. When the storage room is being loaded, it may be necessary to have a large TD just to remove field heat from the fruit. During the holding operation, the TD should be as small as one or two degrees F. To summarize this very important factor, it should be stated that undersized blower equipment is a very common mistake and that it accounts for much of the low relative humidities experienced in some New York storages.

A second factor affecting relative humidity is the dryness of the container material. A very dry, northeastern apple box can absorb as much as one-quarter pound of water during the storage season. This absorption takes place at the expense of the apples. In a 10,000 box capacity room this could amount to as much as 2500 pounds of water or over 300 gallons of water absorbed.

Brine spray cooling units also tend to lower the relative humidity. The salt solution used in brine spray units lowers the vapor pressure of the air. The greater the amount of salt used, the more the relative humidity is reduced.

In view of these considerations a high relative humidity can only be maintained by the following:

1. Keep a small TD between coils and room air.

2. Container wood must be moist. If open field crates are used, wet down each day's loading. This wetting down can be continued until the wood looks a little moist the morning after wetting down.

3. If the relative humidity persists in staying below 90 per cent, water atomizers of different types can be used. One method involves the use of humidifying nozzles along the air distribution duct. One nozzle is placed at every other slot opening. If the room is to be held at 32°F., the water line must be air vented so that the line can be drained free of water when not in use. A strainer in the line will prevent some clogging of the nozzles. Running the atomizers an hour each day should maintain a high relative humidity. It should be remembered that if the coil temperature is too low, much of this added water vapor will just freeze out on the coils.

4. Never use more than the minimum amount of salt necessary in a brine spray unit. Do not add salt until a film of ice begins to form on the coils.

Measurement of relative humidity

The most accurate method of measuring relative humidity is to use a psychrometer. This instrument involves the use of two accurate thermometers. The mercury bulb (base of thermometer) of one thermometer is covered with a cloth wick which is wetted with distilled water. Evaporation of water from the wick causes a lowering of the temperature of the "wet bulb." The relative humidity can be determined from the difference in temperature of the wet bulb and the dry bulb, using table 1.

Table 1. Relative Humidity (%) from Wet and Dry Bulb Temperatures

	Dry bulb minus wet bulb temperatures (at 29" barometer pressure)					
Air temperature	**.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**
30°F.	95	89	84	78	73	68
31	95	89	84	79	74	69
32	95	90	85	79	74	69
33	95	90	85	80	76	71
34	95	90	86	81	77	72
35	95	91	86	82	77	73
36	95	91	87	82	78	73
37	95	91	87	83	79	74
38	96	91	87	83	79	75

The use of wet and dry bulbs is accurate only when there is a rapid movement of air across the wet bulb. This may be accomplished by swinging the two thermometers as with a "sling psychrometer." (figure 5). The swinging is continued until constant temperatures are reached. Another type of psychrometer involves pumping air with a squeeze bulb over the wet bulb. Pumping is continued until constant readings are obtained. This type is less likely to be broken. The stationary type tends to read about 5 per cent high because there is not positive air movement across the wet bulb (see figure 5).

Direct reading humidity indicators are seldom accurate.

Ventilation

The amount of ventilation to use in a refrigerated apple storage has often been debated. By ventilation is meant the introduction of fresh air into the room.

The oxygen level would rarely, if ever, be low enough that air should be added. If the workers in the room feel "uncomfortable" or find that they have to breathe rapidly, the doors should be left open for awhile. Rooms are seldom so gastight (except for controlled atmosphere rooms)

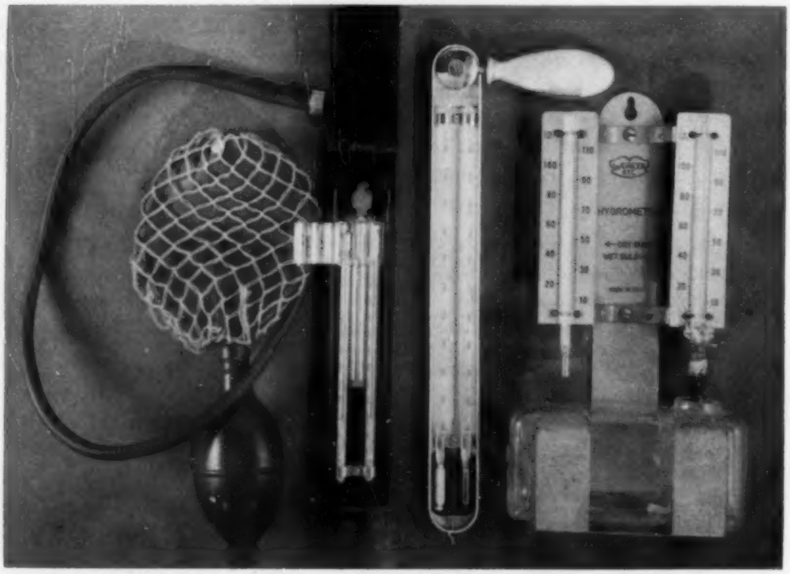


FIGURE 5. INSTRUMENTS FOR MEASURING RELATIVE HUMIDITY
Left: Hand aspirated psychrometer *Center:* Sling psychrometer *Right:* Stationary type psychrometer

that the oxygen level would get this low. For the same reason, carbon dioxide levels would rarely, if ever, get too high.

It has long been thought that the apple scald disease was caused by accumulations of gases given off by the apples themselves. Real control of scald by even frequent ventilation is not practical. Ventilation to be effective must be practiced even early in the season when outside temperatures are high. Even with perfect ventilation, control of scald is not adequate.

If odors accumulate in the room which may affect the flavor of the fruit, ventilation can reduce the odor level.

For all practical purposes, it can be said that ventilation serves little useful purpose. One objection to practicing it is that when outside very cold (and dry) air is used, the relative humidity will be temporarily lowered in the room.

Effect of one lot on another in storage

Another moot question is the possible influence of one lot of apples on another in storage. It is well known that the ripening rate of apples can be stimulated by the presence of ripening gases. Ripe apples give off ethylene which can stimulate the ripening rate of unripe apples. The debatable point is whether or not this effect is important at low storage temperatures.

The magnitude of the ripening effect of one lot of apples on another varies depending upon the following:

1. Storage temperature. The lower the storage temperature the less likely that a ripe lot of fruit can stimulate the ripening of an unripe lot. A number of experiments have shown no effect at 30–32°F. New York experiments have shown effects in some seasons at 33°F. on certain varieties.

2. The season. In experiments with Cortland apples in New York, there have been ripening effects in some seasons and not others. This has been true both at 33° and at 70°F.

3. The maturity of the "ripe lot." Apples do not give off much ripening gas until they are almost in the eating ripe condition.

4. The maturity of the "unripe lot." Only fruits that have not yet begun the respiratory rise (figure 2) will respond to ripe apple vapors. This means that only fruits on the immature side of ripeness will respond to ripening gases. For example, the first picked McIntosh in the season are usually in this condition.

5. The varieties involved. Some varieties such as McIntosh produce more ripening gases than others such as Rome Beauty. Some varieties such

as McIntosh and Cortland are more susceptible to ripening gases than others such as Golden Delicious and Baldwin. A maximum shortening of storage life in a variety like Cortland would be one month. As indicated previously, the effect may be nil.

Air purification

Air purification involves passing the storage room air through beds of 6–14 mesh activated coconut shell carbon.

If a ripening effect of one lot of apples on another is *possible* (see previous section), then air purification may minimize this ripening effect. In short, there is no guarantee that air purification will keep apples longer. Its maximum possible beneficial effect with a variety like McIntosh would be to lengthen its storage life about one month at 32°F. There is also some indication that air purification will protect apples from themselves. Assuming that a given box of apples was picked at the ideal time, there is still a range of maturity within the box of fruit. The riper apples may possibly ripen up the less ripe apples. Air purification tends to minimize this effect in the instances where it is possible.

Air purification may reduce the intensity of scald in some seasons but it cannot be considered a satisfactory scald control measure.

Air purification successfully eliminates undesirable odors in the storage room that may contaminate the flavor of the fruit.

Variety

Varieties differ widely in their inherent length of keeping. McIntosh has a high respiration rate and a relatively short storage life. Rome Beauty has a slower respiration rate and hence a longer storage life. Some varieties such as Twenty Ounce may have a low respiration rate but are very susceptible to low temperature troubles which limit storage life. Good practice demands that all varieties be inspected as to condition in storage and that they be sold before they have passed their prime condition.

Orchard management

Fertilizers

Fertilizer practice can affect the keeping quality of apples. High nitrogen level apples not only are picked in a softer condition but respire faster in storage and may be more susceptible to disorders like brown core in storage. High nitrogen level apples are sometimes larger and also are more subject to disorders such as bitter pit. Figure 6 shows the firmness of McIntosh apples at different nitrogen levels upon removal from

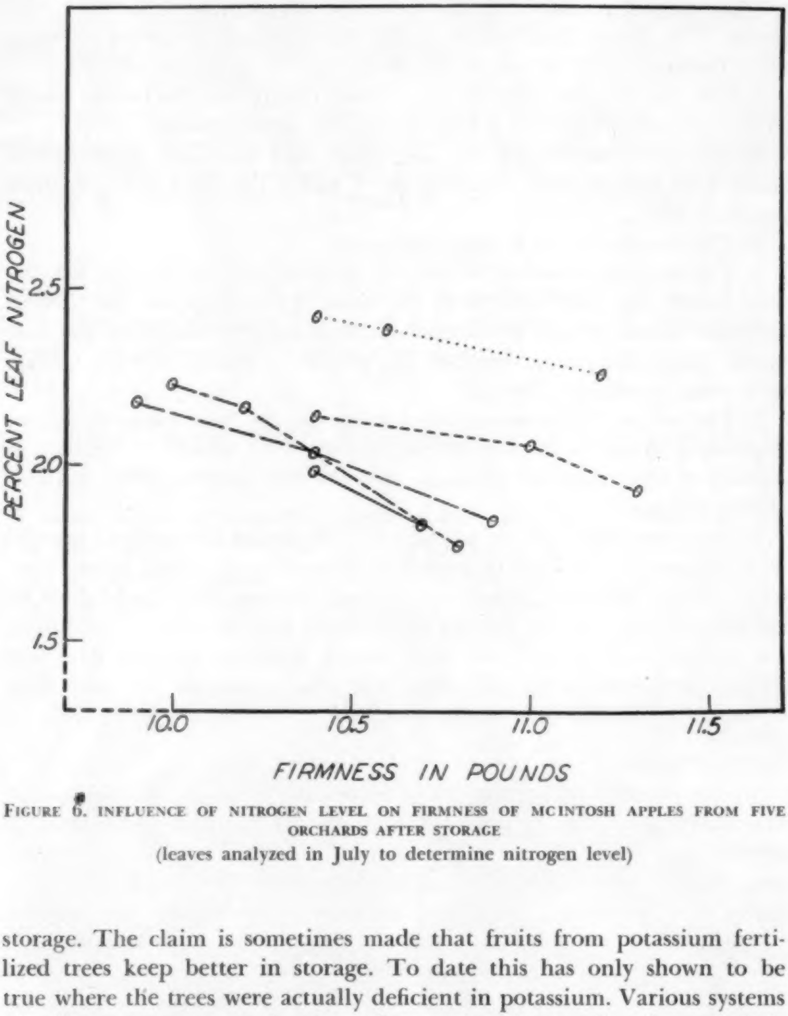


FIGURE 6. INFLUENCE OF NITROGEN LEVEL ON FIRMNESS OF MCINTOSH APPLES FROM FIVE ORCHARDS AFTER STORAGE
(leaves analyzed in July to determine nitrogen level)

storage. The claim is sometimes made that fruits from potassium fertilized trees keep better in storage. To date this has only shown to be true where the trees were actually deficient in potassium. Various systems of soil management can have an effect on keeping quality through their effect on moisture supply and nitrogen level.

Stop-drop hormones

When apples are sprayed with stop-drop materials, the keeping quality may or may not be affected. There may be both a direct and an indirect effect of these materials. The indirect effect would be that sprayed trees

are not picked as soon and the apples go into storage in a riper condition. The direct effect would be that the material stimulates ripening rate. The magnitude of this direct effect depends upon the following:

1. The variety. An early or mid-season variety like McIntosh would show a greater effect than a late variety like Rome Beauty.

2. The hormone. Among the commonly used hormones, naphthalene acetic acid has the least ripening effect and 2,4,5–TP has the greatest ripening effect.

3. The concentration of hormone used.

4. The interval between the date of spraying and the date of harvest. The longer the interval between the time of spraying and the time of harvest, the greater the likelihood of increased ripening from the hormone. This refers primarily to the fact that the apples go into the storage in a riper condition, however.

5. The season. The ripening effect seems to vary from season to season, depending upon the climate during the growing season. Generally, in seasons of high sunshine intensity there is less ripening effect than in cloudy seasons.

In summary, there may be no effect from hormone sprays. Fruit sprayed with 20 parts per million of naphthalene acetic acid 6 days before optimum picking date and picked on optimum picking date should show no reduction in storage life. On the other hand, fruit sprayed with 20 parts per million of 2,4,5–TP one week before optimum picking date and picked three weeks later will often have reduced storage life. Such fruit in some years should not even be stored.

Spray program

Studies on the keeping quality of apples as affected by fungicides and insecticides have been conducted both in the Hudson Valley and in western New York. If a material (like sulfur) is actually injurious, sprayed fruit enters the storage in a slightly riper condition and cannot be expected to keep very well. It is sometimes claimed that one organic fungicide gives better keeping quality than another. This has not been substantiated in our studies. It is sometimes claimed that the use of mild fungicides has increased the incidence of scald. This claim is still under investigation.

Climate

We know that apples do not keep equally well every season in storage. Carefully conducted experiments on the effects of climate have not been conducted. When keeping quality in a given season has been correlated with climactic factors during the growing season, several observations have

been made. In general, McIntosh apples are firmer and keep somewhat better after seasons of high light intensity. Brown core is usually worse after seasons of cool, cloudy weather. Scald is usually but not always worse when the average temperatures during the last six weeks of the growing season are high. There are many possible climatic effects that are not yet fully understood. For example, it is possible that apples may soften unusually fast in seasons when there has been a drought during most of the season followed by heavy, late rains before harvest.

Size of fruit

Oversized apples do not keep as well in storage as normal sized fruits. Very light crops resulting from frost damage in the spring or excessive thinning usually results in poor keeping fruits.

STORAGE TROUBLES AND DISEASES OF THE APPLE

Storage scald

A COMMON storage trouble in varieties such as Cortland, Rhode Island Greening, Northwestern Greening and Rome Beauty is storage scald. Few varieties are completely immune. Scald first appears on the unblushed or green side of the fruit. It has a characteristic burned or scalded appearance. At first the discolored area is firm beneath the skin since the injury

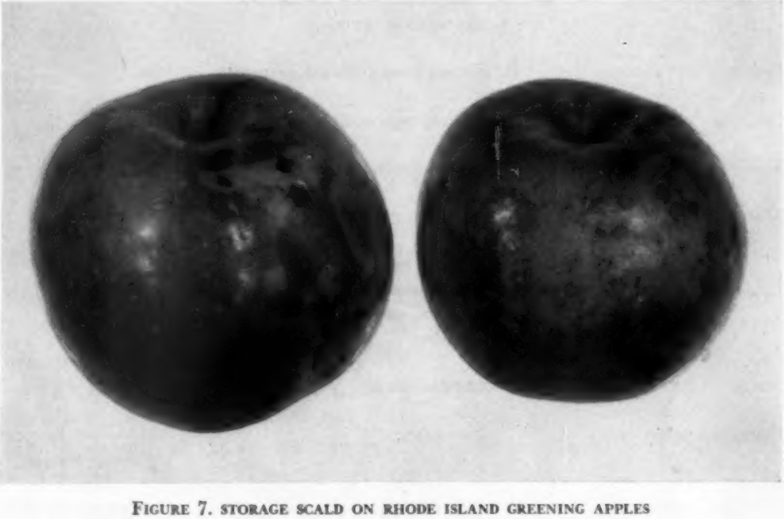


FIGURE 7. STORAGE SCALD ON RHODE ISLAND GREENING APPLES

is confined to the skin (figure 7). Later the flesh immediately below the affected skin becomes soft and secondary infection by rot organisms can occur.

The cause of scald has often been said to be due to accumulations of the odorous gases that apples give off. The exact cause is not known. Table 2 summarizes some of the factors that influence the intensity of scald. The standard method of control for many years has been oiled paper (18–20% by weight of pure, tasteless white mineral oil) wraps or one-half pound of shredded oiled paper per box of fruit. The method does not always control scald. Certain chemicals such as diphenylamine will control scald but they cannot be used unless approved by the Food and Drug Administration.

Table 2. Factors Affecting Apple Scald

Factor	Effect on scald	Undesirable side effects of treatment
	Orchard conditions	
Climate	Usually worse after warm growing season	
Nutrition		
High nitrogen	Increases it on some varieties, decreases it on others	
Pruning	Usually less with well pruned trees	
Crop size	Usually worse on large fruit	
Spray program	Uncertain	
Maturity at harvest	Immature fruit much worse	
	Post-harvest conditions	
Delayed storage	Slight lessening before regular storage; may make it worse in CA storage	Ripens fruit
Waxes	Erratic effects	
Oil sprays and dips	Decrease	Possible off flavors; Use unapproved
Chemical inhibitors	Decrease	Unapproved (1958)

Factor	Effect on scald	Undesirable side effects of treatment
Oiled paper	Decreases	
Unsealed box liners	Increase	
Sealed box liners	Decreases	Possible off flavors
	Storage	
Temperature	Most varieties less scald with low temperature. Cortland may have more	
Oxygen level	Rapid drop in CA storage decreases scald	
Carbon dioxide		
Carbon dioxide treatment	Decreases	Danger of injury
Controlled atmosphere storage	Decreases	Requires CA rooms
Ventilation	Theoretical decrease but often no effect	
Circulation .	Not a lasting decrease	
Air purification	Inadequate decrease	
Ozone	Possible decrease	May injure fruit
Presence of other varieties	Possible increase Sometimes no effect	

Fungus troubles

Blue mold rot

Blue mold (Pencillium expansum) is the most common and most destructive of all the rotting organisms that attack apples. It appears on all varieties as soft, watery spots of a light-brown to light-yellow color (figure 8). If the air around the fruit is moist, a surface growth of the mold may appear. It occurs also as small tufts of whitish and later blue-green grain like structures (spores) on the rotted area. The rotted fruits impart a musty odor.

FIGURE 8. BLUE MOLD ROT ON APPLES

Practically all of the rot due to this fungus results from skin breaks in the fruit. Hence, the main approach to control is through careful handling. Prompt storage and rapid removal of field heat help to hold down this disease. The rot will grow even at 30°F, however. The rot develops faster at high relative humidities, but these are necessary in fruit storage. Treating the fruit after harvest with .6 per cent of sodium phenylphenate tetrahydrate in the acid wash for spray residue removal followed by a water rinse will inhibit rot development. Treatment with .3 per cent of this material is used when a water rinse is not used. Since spray residue removal by washing is not common in New York, this rot control treatment has not been adopted as yet in this state.

Gray mold

This fungus (Botrytis) causes a rot similar to that caused by blue mold, but the affected area is firmer and has a sour taste in contrast to the musty taste of blue mold apples (figure 9). It spreads from apple to apple and causes "rot nests" in boxes of fruit.

Prompt storage and rapid field heat removal holds down this rot, but it will develop even at 30°F. The sodium phenylphenate tetrahydrate treatment described under blue mold will help control it.

Apple scab

The scab disease will develop in storage if there is a late season infection resulting in "pin point" inoculation in the orchard. Control measures lie

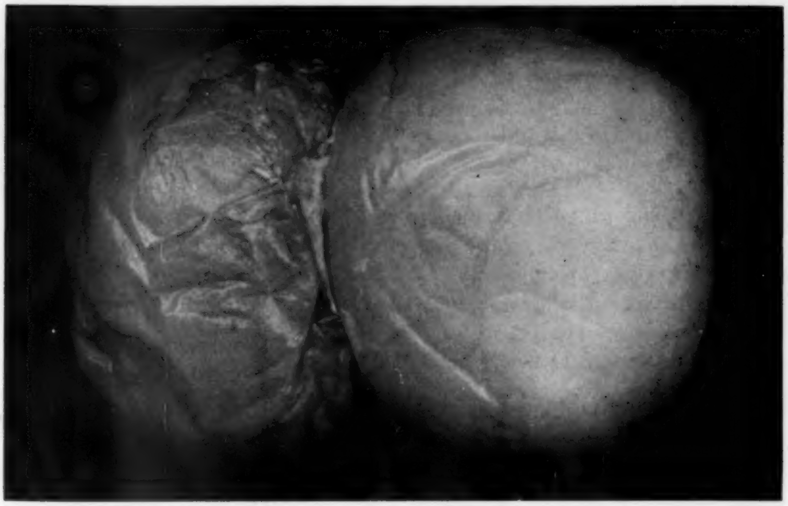


FIGURE 9. GRAY MOLD DECAY

in the orchard. It does not spread in storage from apple to apple. The scab spots which may have been invisible at harvest time merely grow in size.

Pink rot

This fungus usually causes rot spots around the margins of scab lesions. The affected portion becomes firm, corky, dry and has a bitter taste. In the late stages, the fruiting bodies may give the rot a pink appearance.

Bulls' eye rot

This disease is characterized by a light brown discoloration with the center of the rot lighter in color than the margin, giving a bull's eye effect. The surface of the rot is depressed and the flesh beneath is dry and leathery. Control measures lie in the orchard.

Black rot

This is an orchard disease that may develop in storage. It results in a very black discolored rotted area. The rotted regions usually have a marked zoned appearance.

Brown rot

This is an orchard disease that resembles black rot but has a more velvety appearance. It may develop in storage.

Alternaria rot

This is an orchard fungus that attacks varieties with open calyx tubes in particular. It causes a rotting of the core region. On Northern Spy this fungus sometimes makes spots that resemble Jonathan spot, although they appear on the yellow side of the apple as well as on the red. See figure 16.

Bitter rot

This rot is typified by brown or black, slightly sunken, rotten areas. Numerous small, black pustules can usually be seen just beneath the skin or just breaking through it. They are arranged in a circle and usually have pink fruiting bodies at their tips. Another type of bitter rot which may appear more commonly in storage is one which may cause red or purple spots or specks with a dark center.

Surface growing molds

A number of molds such as blue mold can grow on the surfaces of the fruit, on boxes, and on the walls if the relative humidity is high. These fungi only grow in surface films of water resulting from local condensation of water. Good air circulation in the room tends to prevent this local condensation. These molds have sometimes been called "whiskers" because of their excessive growth (figure 10). While these surface growing molds do not enter the fruit, they do make it unsightly and impart a musty odor to the fruit. A high relative humidity is necessary in storage so they should be controlled by lowering the humidity below 90 per cent. As noted before, good circulation of the air will help prevent their growth.

FIGURE 10. SURFACE-GROWING MOLDS ON FIELD CRATE

Low storage temperatures help slow down their growth. Mold growth on the containers can be fairly well controlled by treating the wood with the proper fungicides. If the walls and ceiling build up a heavy mold spore population through the years, it is wise to clean them periodically. Sprays of calcium or sodium hypochlorite solution which liberate free chlorine can be used. Directions for dilution to get about 2000 parts per million of active chlorine usually appear on the hypochlorite containers sold under various trade names. After quickly spraying the room when it is empty, the room should be left closed for 12–24 hours. Then it should be thoroughly aired and dried out before using it again. Care must be taken not to inhale too much of the chlorine since it is a poisonous gas. The chlorine will give warning, however, since it causes coughing.

The use of one to two parts per million of ozone once a day for an hour will usually control all surface molds. Continued use of even two parts per million can cause the skin of the fruits to become sticky or even develop spot injuries. If ozone is used, it should be generated during periods when men are not working in the rooms since it is irritating to the mucous membranes. Ozone will decompose any rubber (such as door gaskets) in the room. The electrical generation of ozone is not a cheap process and ozone is not commonly used for this reason.

Bitter pit

Bitter pit, stippen, or Baldwin spot are all the same trouble and affect varieties such as Baldwin, Northern Spy, and Rhode Island Greening (figure 11). Bitter tasting, small brown spots or streaks develop just under

FIGURE 11. BITTER PIT, OR STIPPIN, ON NORTHERN SPY (LEFT) AND ON BALDWIN (RIGHT)

Table 3. Factors Affecting Bitter Pit

Factor	Effect on bitter pit
	Orchard conditions
Climate	
Periods of competition for water between fruits and leaves	Make it worse
Dry periods followed by wet periods	Said to make it worse
Nutrition	
High nitrogen levels	Make it worse
Low calcium	Claimed to make it worse (not proven)
Crop size	Large apples much worse
Pruning	Heavy pruning can make it worse but shaded fruits get more
Ringing	Makes it worse
Maturity	Early picked fruits get more
	Storage conditions
Prompt storage	Makes it less
Low temperature storage	Makes it less
High relative humidity	Makes it less

the skin or sometimes anywhere in the flesh. Apples badly affected with bitter pit are not marketable.

Strictly speaking, bitter pit is not a storage trouble but rather is an orchard induced disease. Although apples apparently free of bitter pit will develop the trouble in storage, it affects only apples made susceptible in the orchard. Table 3 outlines these factors affecting susceptibility to bitter pit.

Low temperature troubles

Freezing damage

It is obvious that if apples are held at temperatures of 29°F or lower they will freeze. The amount of damage done by freezing is a matter of

degree. If they are lightly frozen, the thawed apples may appear quite normal. These fruits have a faster than normal ripening rate and should be sold rather soon after freezing and thawing has occurred. If the apples are thoroughly frozen, the flesh will turn brown and watery on thawing. If it is discovered that apples are at the freezing point judging from a thermometer, it is sometimes better not to move them. In any case, it is wise to leave the apples in place and not touch them until the temperature has been raised above the freezing point and the apples have thawed. It is sometimes claimed that slow thawing results in less injury than fast thawing. This would only apply if the apples were just lightly frozen. If they are completely frozen, it doesn't matter how they are thawed—they will be ruined.

Brown core

It is obvious that freezing damage is a low temperature trouble. It is less obvious that some varieties can develop diseases when held at above freezing temperatures. Among these troubles is brown core or core browning or core flush (figure 12). It is characterized by a premature browning of the flesh around the core. It is first noted as a slight discoloration between the seed cavities. In true brown core, the flesh is firm and crisp even though it is brown. There is a senescent or old-age type of brown core also which comes in overripe apples. In senescent brown core the flesh is rather dry and flaky in the affected brown areas.

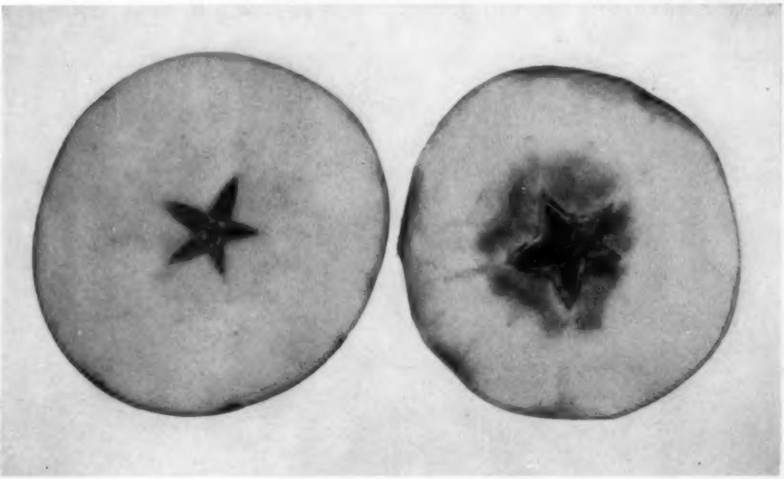


FIGURE 12. BROWN CORE IN MCINTOSH (RIGHT) STORED CONTINUOUSLY AT 32° F. IN AIR, AND NORMAL MCINTOSH (LEFT) STORED CONTINUOUSLY AT 40° F. IN CONTROLLED ATMOSPHERE

Brown core is often serious on McIntosh, Baldwin, Rhode Island Greening and Twenty Ounce. It is usually more serious after growing seasons have been rather cool and cloudy. It is often made worse by heavy fertilization with nitrogen fertilizers. Immature fruits are more susceptible than mature fruits. Large fruits get the trouble worse than small ones. The only known cure is storing the apples at 37°F. or higher. In controlled atmosphere storage no brown core should be experienced with a variety like McIntosh because temperatures of 37–38°F. are used.

Internal browning

This trouble is sometimes seen on Rhode Island Greening and Yellow Newtown when stored below 37°F. It seems to be worse after cool, cloudy growing seasons. The affected tissues are brown but remain firm and radiate from the core area. It differs from brown core in that the diseased portions radiate farther from the core area. The affected areas are firm and juicy. The only known cure is to store at 37°F. or higher.

Soft scald

Soft scald is sometimes seen on Jonathan, Winter Banana, Golden Delicious, and Northwestern Greening. It is characterized by blister-like, sunken areas that extend in irregular patterns over the skin of the fruit. These areas are often curved and often result in the formation of islands of normal tissue (figure 13).

Studies in Washington with Delicious have shown that 8 weeks storage at 34°F. prior to 31°F. will protect apples against soft scald. With vari-

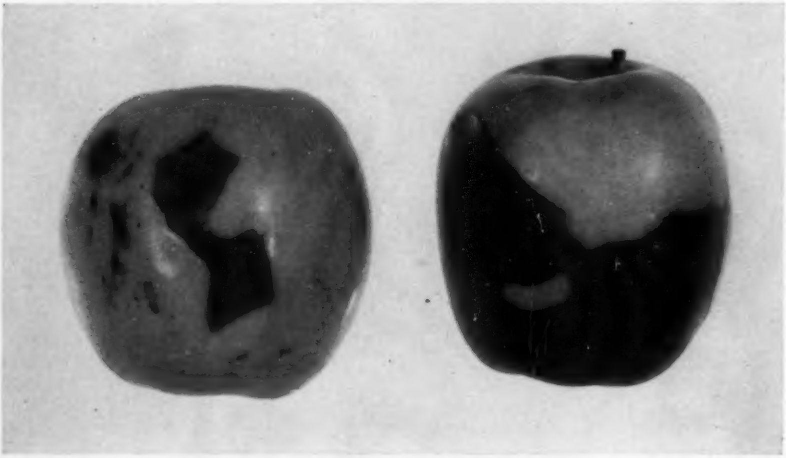


FIGURE 13. SOFT SCALD ON APPLES IN STORAGE

eties like Jonathan continuous storage at 38°F. is often necessary. Controlled atmosphere storage even at 32°F. shows promise in controlling this trouble in Jonathan.

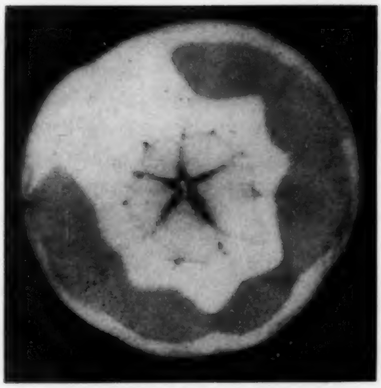


FIGURE 14. SOGGY BREAKDOWN IN APPLES

Soggy breakdown

Soggy breakdown resembles soft scald except that it is inside the apples. The apples have to be cut to see it. The inner part of the flesh becomes brown, soft, and in severe cases a complete ring of soft, brown, spongy tissue is present. There is a sharp line of demarcation between healthy and diseased areas (see figure 14). Prompt storage at temperatures of 37–38°F. are the only known cure for this trouble.

Internal breakdown

There are a number of types of internal breakdown in varieties such as Twenty Ounce, Stayman, and McIntosh (figure 15). Whether slightly different symptoms of the disease indicate different diseases is not known. For all practical purposes it can be said that mealy breakdown, internal

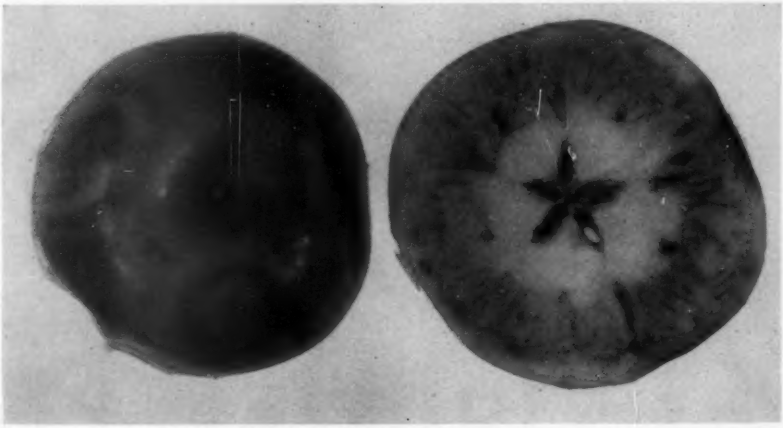


FIGURE 15. INTERNAL BREAKDOWN
Injury was not visible from the outside of the fruit

breakdown and other designations are really signs of premature old age. These troubles are characterized by soft, dry, crumbly flesh. The breakdown can usually be discovered by pressing the outside of the fruit with a finger. In the later stages, the outer portions of the apple turn brown and the apple may split open. The exact causes are not known for these troubles. Large apples are especially affected and the trouble is much more serious in some seasons than in others. Prompt storage at 30–32°F. minimizes the trouble. Late picked fruit is usually worse than early picked fruit.

Jonathan and Northern Spy Spot

Jonathan and Northern Spy spot are two similar troubles although the appearance of the two diseases is slightly different. The spots start as minute brown or black spots but often increase in size to one-eighth-inch or more. The spots are more serious on the red side of the fruit. They are often more numerous on the stem end of the fruit. On Northern Spy, the spots could be confused with Alternaria spots (figure 16). These troubles are worse on late picked, well-colored apples. Controlled atmosphere storage controls both troubles very well.

FIGURE 16. ALTERNARIA ROT SPOTS (LEFT) AND NORTHERN SPY SPOT (RIGHT)

Water core

Water core is a non-parasitic trouble that affects such varieties as Northern Spy, Rhode Island Greening, Delicious, and Tompkins King. It is characterized by a glassy, water-soaked appearance. It is especially severe in regions or seasons of intense sunlight and high temperatures. The disease does not develop in storage, but is essentially an orchard disorder. Mild cases of water core may disappear upon continued storage, but severely affected fruits break down rather quickly in storage. There is no known control.

Fruit shrivel

Fruit shrivel is more of a disorder than a true disease. Excessive water loss in storage causes wrinkling or shrivel of the skin. Golden Delicious is particularly susceptible. By the time apples have lost 5 per cent of their original weight, they usually show severe shrivel (figure 17). Apples should not lose more than two to three per cent of their weight in storage.

To prevent shrivel the principles outlined under "transpiration" (page 11) must be observed. Prompt storage, fast cooling, and storage at 30–32°F. in 90 per cent relative humidity will minimize weight losses.

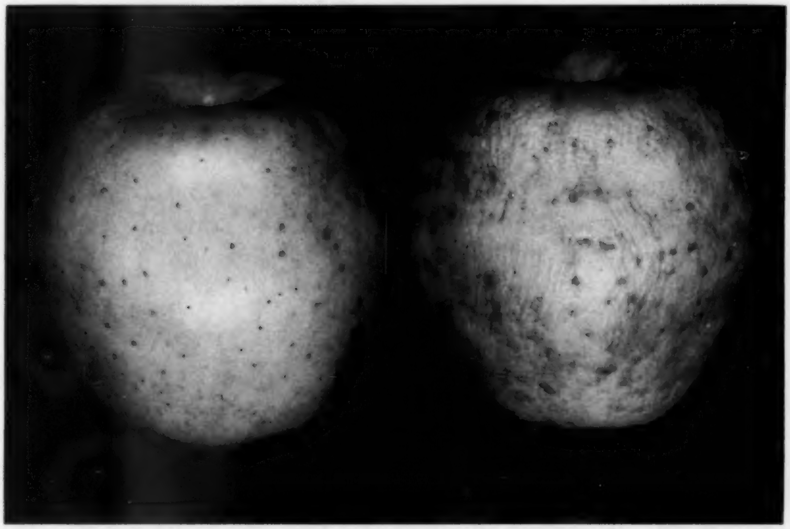


FIGURE 17. GOLDEN DELICIOUS STORED IN HIGH RELATIVE HUMIDITY (LEFT) AND LOW RELATIVE HUMIDITY (RIGHT)

Sometimes box liners of aluminum foil or plastic films such as 150 gauge polyethylene are used to prevent weight losses. Unsealed liners of this type are very effective in preventing shrivel. There are certain hazards, however. Decay is likely to be more severe unless fungicidal treatments are given. Scald is likely to be much worse. Sealed 150 gauge polyethylene box liners will usually reduce the scald if the liners are gastight. Sealed liners also control shrivel, but there are dangers of off flavors and carbon dioxide injury. Either sealed or unsealed box liners should only be used with these hazards in mind.

Coating apples with fruit waxes will reduce losses from shrivel. They are not as effective as box liners in this regard. Water emulsion waxes must be dried after application and this adds expense to the handling operation. Grease type waxes which do not require drying leave the fruit looking oily. Water emulsion waxes give the fruit a bright luster.

Off odors

If undesirable odors accumulate in a storage, they can taint the flavor of the fruit. Mixed produce storage is advised against for this reason. For example, potatoes, cabbage, or onions will contaminate the flavor of apples. Some building materials such as yellow pine will produce strong piney odors which the apples can absorb. Apples will pick up paint odors or the odor of creosote of freshly treated wood. Surface molds (see page 28) will produce strong musty odors. Undesirable odors should be avoided rather than controlled. Air purification with activated coconut shell carbon (see page 20) will remove most undesirable odors.

Rodents

Field mice or rats are sometimes a trouble in apple storage. Field mice are particularly a problem when apples are stored field run. The longer the field crates sit in the orchard before gathering up, the greater the likelihood of the introduction of mice into the storage. The greater the population of field mice in the orchard, the more likely they are to be a problem in storage.

Field mice nibble on many apples and destroy their marketability. Rats usually feed on the seeds. It has been estimated that one rat can do 100 dollars worth of damage.

Baiting with rodent bait in the aisles of the storage will sometimes catch the mice or rats if they are not numerous. There is so much food for these animals feeding on apples that they usually are not attracted to the baits.

Fumigation, when properly done, is very effective. It does leave the dead bodies of the rodents in the storage, but this is better than having their filth and the damage they do. The bodies tend to dry up and do not cause off odors at storage temperatures. When fumigation is done, it is a good idea to have caged field mice spotted around the room to determine how effective a job has been done. There is little point in fumigating until all the fruit has been placed in storage.

All the fumigation gases are poisonous to humans and should be treated with the greatest of respect! Fumigation should be done at night when workmen are out of the rooms. Doors should be sealed and barred to prevent any possible entry by a human. Some of the gases used are harmful to the apples when used in over dosages. Chlorpicrin should never be used either alone or in combination with other gases.

Twenty per cent carbon dioxide in the atmosphere for five hours will kill all rodents. The disadvantage in using this gas is that high concentrations must be used. It requires practically a gastight building.

Carbon monoxide from gasoline motor exhausts is very effective in killing rodents. Very little is known about the accurate use of this gas. In one test in Canada, a 60 horsepower motor run for 5 hours in a 100,000 cubic foot capacity room did a good job. In another test, a 36 horse power tractor motor did a good job in 2¼ hours in a 50,000 cubic foot room. Use of carbon monoxide is very dangerous because of its extreme toxicity to humans. The rooms must be thoroughly aired out after fumigation before entering the rooms. It is also very difficult to estimate how long to run a given motor to get effective results.

The most commonly used chemical for fumigation is methyl bromide. This also is a deadly gas but when properly used it is quite safe. Measured quantities of gas can be used and a gas mask with an organic canister is used to prevent inhaling the gas. Methyl bromide is sold in one pound cans so the quantities used can be fairly closely estimated. One-quarter pound of methyl bromide per 1000 cubic feet of free air space is used. If the room is full, it is estimated that half of the air space is occupied by fruit and containers. The gas is left in the room for five hours and then ventilated thoroughly. A halide detector (as used for detecting Freon 12 leaks) will indicate whether the gas has been completely removed from the room. Of course, a gas mask is worn while applying the gas through a copper tube into the room and while testing the room to see if it is sufficiently ventilated. Full details on the use of this method can be had by writing the Department of Pomology at Cornell University. Over-dosages of methyl bromide can injure the fruit very badly. The fruit should not have any free water on it when it is treated.

WATCHING FRUIT CONDITION IN STORAGE

Fruit should be removed from cold storage and sold before it is "out of condition." Sale of fruit that is badly affected with brown core, scald, soggy breakdown, or if too ripe hurts the reputation of stored fruit. The storage operator can not forsee all of these difficulties, but by watching fruit closely he can sell the fruit before disease or overripeness becomes serious.

Representative samples of different varieties in storage should be examined at least every two weeks. Of course, with a long-keeping variety such as Northern Spy, it may not be necessary to start the bi-weekly inspections until January or February. These representative samples of at least 50 apples each should be examined as to fruit firmness, eating quality, and possible storage disorders. Some storage disorders, such as decay, can be determined immediately upon removal. Others will become evident only after several days at room temperature. For example, the Rhode Island Greening may be watched after December 1. If, at the first examination there is no evidence of scald or bitter pit after a seven-day holding period at room temperature (70°F.) and the apples are still firm, it is assumed that the general condition is still good. If after a three-day holding period early in January there is a small percentage of scald, these apples should be moved fast because scald is rather certain to increase in severity. The whole object of this periodic inspection after a holding period at a high temperature is to try to anticipate storage disorders.

Besides watching for fruit diseases, the storage operator can easily determine fruit firmness with a pressure tester of the Magness-Taylor type. Firmness is a fairly good indication of general ripeness. The use of the pressure tester is not a good index of when to pick apples because firmness varies with culture, season, and other growing conditions. The pressure tester is, however, a useful tool in watching the general softening rate of a given lot of apples.

Table 4 may be used as a general guide to evaluate the softness of several common New York varieties. The third column in table 4 gives the general range in firmness when the different varieties are in a "firm ripe" or "prime" condition. The fourth column includes the pressure test below which apples should not be kept in storage. They are edible at this pressure test but should be sold before reaching these figures, because they will still have to go through the marketing channels before reaching the consumer. The last column gives the figures at which the different varieties are "unmarketable" because of softness.

Table 4. Determination of Fruit Condition with the Pressure Tester

Variety	Firmness when harvested	Firmness when "prime" or "firm ripe"	Should be sold before reaching	Unmarketable
	Pounds	*Pounds*	*Pounds*	*Pounds*
Duchess	17 to 19	11 to 14	11	7 to 9
Wealthy	14 to 16	11 to 14	10	7 to 8
McIntosh	14 to 16	11 to 12	10	7 to 8
Cortland	16 to 18	12 to 13	10	8 to 9
Delicious	17 to 18	12 to 15	11 to 12	8 to 10
Golden Delicious	18 to 20	13 to 16	12	8 to 10
Jonathan	16 to 19	11 to 14	11	8 to 10
Rhode Island Greening	21 to 24	14 to 16	13	10
Baldwin	22 to 24	13 to 14	12	10
Northern Spy	19 to 22	13 to 17	12	10
Rome Beauty	19 to 21	13 to 17	12 to 13	10

While the figures given in table 4 were collected from actual experiments, they are intended only as a rough guide. The variety McIntosh has been rather thoroughly tested in connection with this table but others have not. There are also certain "subjective" features to such a table. For example, some persons might consider McIntosh unmarketable at 10 pounds.

The pressure test is made by taking a shallow slice off the surface of the apples. This slice should expose an area of flesh somewhat larger than the 7/16-inch plunger on the pressure tester. On blushed apples the test should be taken on the green side of the fruits, since the test usually runs somewhat higher on the blushed sides. One can take two or more tests per fruit if he wants to. The fruit should be held against a solid background and the plunger on the pressure tester pushed slowly but steadily in a horizontal position until the 7/16-inch mark on the plunger is reached. The pressure test is then read directly off the scale on the tester.

After the apples become somewhat shriveled in storage, the use of the pressure tester must be discontinued. Such apples are spongy and rubbery and give an abnormally high pressure test reading.

Sometimes it is desirable to know approximately the potential storage life of a given lot of apples. It may also be desirable to know about how long a given lot of apples will remain marketable at room temperature following removal from cold storage. Tables 5 and 6 were prepared for

McIntosh apples from actual information with this variety. Even so, the tables can only be considered an approximation since many conditions other than firmness alone may determine storage life.

Table 5. Length of Marketability Period for McIntosh in 32°F. Air

Firmness when placed in storage	Days at 32°F. required to reach		
	10 Pounds	11 Pounds	12 Pounds
Pounds	*Days*	*Days*	*Days*
16	130	110	90
15	110	90	70
14	90	70	50

Table 6. Length of Marketability Period for McIntosh Apples when Removed from 32°F. Air Storage and Held at 74°F.

Firmness when removed from storage	Days required to become unmarketable after being removed from storage *
Pounds	*Days*
14	18
13	15
12	12
11	9
10	6
9	4
8	2
7	0

*Refers to number of days required to reach 7 pounds firmness. McIntosh should reach the consumer when no softer than 9 pounds and preferably firmer. These figures assume that the apples are not allowed to shrivel during the holding period at 74° F.

A Publication of the
New York State College of Agriculture,
a unit of the State University of New York,
at Cornell University, Ithaca, New York

Revised May 1958

Cooperative Extension Service, New York State College of Agriculture at Cornell University and the U. S. Department of Agriculture cooperating. In furtherance of Acts of Congress May 8, June 30, 1914. M. C. Bond, Director of Extension, Ithaca, New York.